respect to all the 10 characters? What proportion will be homozygotic with respect to any given one character? To any two or three?

Taking first the case for the entire 10 characters, by formula (1)

$$x = \left(\frac{2^8 - 1}{2^8}\right)^{10} = \left(\frac{255}{256}\right)^{10} = \log.\ 9.9830020 = .961617.$$

Thus, out of 100 individuals, somewhat above 96 would be pure homozygotes; or by formula (4), but one in 26 would be heterozygotic in any respect ($v = .038383$).

With respect to any one character formula (1) gives

$$x = \left(\frac{2^8 - 1}{2^8}\right)^1 = \frac{255}{256} = .99609375,$$

so that all but 4 in 1,000 would be homozygotes with respect to that character.

In the same way we find that with respect to any two characters the proportion of homozygotes would be .9922; with respect to three, .9883; with respect to four, .9845, etc.

(2) Suppose that there are 20 pairs of characters, and that there have been 20 self-fertilizations. Then

$$x = \left(\frac{2^{20} - 1}{2^{20}}\right)^{20} = \left(\frac{1{,}048{,}575}{1{,}048{,}576}\right)^{20} = \log.\ 9.9999957 = .999998.$$

That is, of a million individuals, all but two would be pure homozygotes.

It thus appears that if the number of separably heritable characters is not very great (say not above 100), while the organism has been self-fertilized for many generations, it is to be expected that practically all of the organisms will be homozygotic with respect to all their characters, they will be "pure homozygotes."

H. S. Jennings

## YELLOW AND AGOUTI FACTORS IN MICE NOT "ASSOCIATED"

In a recent number of the American Naturalist Mr. Sturtevant[1] suggests that these two color factors may bear to each other the relation which Bateson has called "repulsion" or "spurious allelomorphism" and which Morgan now includes with "coupling" in a more general category, "association." The supposed

[1] Sturtevant, A. H., "Is there Association Between the Yellow and Agouti Factors in Mice?" Am. Nat. Vol. XLVI, No. 546, p. 368, 1912.

relation is such that the characters involved fail to pass into the same gamete even though they may be present together in the parent zygote. That yellow and agouti in mice are not in general so related is shown conclusively by experiments which will be more fully described elsewhere, but which may be briefly summarized in the following table:

| Mating | Parents | Offspring | | |
|---|---|---|---|---|
| | Both Yellow | Yellow | Agouti | Black or Brown |
| 185 | 894 × 895 | 1 | 1 | 5 |
| 10 | 502.2*A* × 502.5*A* | 10 | 2 | 1 |
| 397 | 3,908 × 875 | 4 | 2 | 2 |
| 273 | 2,049 × 875 | 5 | 1 | 1 |
| 159 | 786 × 784 | 5 | 3 | 1 |
| 446 | Unmarked × 4,054 | 8 | 6 | 2 |
| 500 | Unmarked × 4,152 | 2 | 3 | 1 |
| 545 | Unmarked × 4,152 | 4 | 2 | 1 |
| 467 | 4,524 × 4,523 | 9 | 1 | 1 |
| 519 | Unmarked × 4,631 | 6 | 2 | 1 |
| 543 | ——— × 4,905 | 2 | 1 | 3 |
| 397 | 3,908 × 875 | 4 | 2 | 2 |
| 240 | 1,828 × 1,829 | 10 | 1 | 6 |
| 113 | 562 × 563 | 6 | 3 | 2 |
| 173 | 1,074 × 563 | 2 | 1 | 2 |
| | Total | 78 | 31 | 31 |

In these experiments yellow animals bred *inter se* have produced non-yellow young half of which are agouti and half of which are non-agouti. It seems therefore to be wholly a matter of chance whether a yellow animal heterozygous in agouti transmits that character *with* yellow or apart from it. Sturtevant's contrary conclusion is due in part to his reliance on the insufficient numbers observed by Morgan and in part to his overlooking certain of the results reported by Miss Durham. For, in addition to the category of matings of yellow mice cited by Sturtevant, she reports matings of sable (yellow) mice *inter se* which produced 17 sable (yellow), 8 yellow, 5 agouti, 4 black, and 2 brown young, a result in harmony with that which I have described.

In the matings reported by Miss Durham in which yellow parents produced only yellow young and agouti young, it seems probable that one or both of the yellow parents was homozygous in agouti. The same was probably true in the similar experiments of Morgan. This would explain why all the non-yellow young were agouti marked.

As further evidence that yellow and agouti are wholly independent characters may be cited experiments of my own in which yellow animals evidently heterozygous in agouti were

mated with brown animals which invariably lack agouti. There were produced 15 young, of which 7 were yellow, 5 agouti and 3 black or brown. Evidently the yellow parent transmitted non-yellow (black or brown) in 5 cases associated with agouti, and in 3 cases not so associated. On Sturtevant's hypothesis all non-yellow young should have been agouti.

C. C. Little

Laboratory of Genetics,
Bussey Institution, Harvard University,
June 17, 1912

## PHYSICAL ANALOGIES OF BIOLOGICAL PROCESSES

Two schools or methods of thinking of heredity and other general problems are recognized among biologists. Some hold that all biological phenomena are to be explained in terms of physical and chemical properties of unorganized matter. Others are inclined to believe that the activities of living matter represent agencies or relations not shown in the inorganic world. The first view has been called materialism, the second vitalism.

These distinctions are not as important as sometimes supposed, because of our inadequate knowledge of the properties of matter, whether organic or inorganic. The materialistic view may be said to have a practical advantage in encouraging the investigation of the physical and chemical phenomena of the organic world, but vitalism may claim at least an equal advantage in permitting the recognition of facts that lie on the other side of the biological field, where the analogies of physics and chemistry find little or no application. Thus the specific constitution or speciety of living matter, the fact that organisms maintain their existence and make evolutionary progress only in groups of individuals united into specific networks of descent, involves the recognition of a condition or property quite foreign to the usual conceptions of the physicist or the chemist. Yet this universal condition of speciety must be considered as a general basis or background for any strictly biological study of the organic world. We may count, weigh, measure or analyze the bodies and activities of organisms from as many other standpoints as we please, but it is idle to draw general biological conclusions from any merely mathematical or physical data. The true biological significance of statistical and physical facts has to be determined by biological analysis.

As long as physical and mathematical analogies add something to our comprehension of biological facts they are entirely